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ABSTRACT

This curriculum guide is designed for instructors of secondary industrial arts, vocational, and apprenticeship programs. The material is presented in two sections. Section I provides step-by-step instructions on how to present basic electrical circuit concepts with the use of a simply-made breadboard. Included in this section is the following information: a curriculum outline; an introduction to breadboarding; a list of the electrical hardware needed; a description and illustration of the basic breadboard; and the components of a breadboard. Section II builds on these basic concepts to demonstrate basic house wiring techniques. This section includes the following topics: a curriculum outline; an introduction to the wiring frame method; a list of the house wiring hardware needed; a description of the wiring frame assembly; and four wiring frame exercises. Also included in this guide is a list of texts and related resource information. (Author/JH)

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ED154219

a curriculum package for
implementing instruction in.....

ELECTRICITY FUNDAMENTALS

HOUSE WIRING

by Brian P. Murphy

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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1978

MARYLAND VOCATIONAL CURRICULUM RESEARCH AND DEVELOPMENT CENTER
Department of Industrial Education
University of Maryland
College Park, Maryland 20742
in cooperation with the Maryland State Department of Education

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FOREWORD

STOP AND READ THIS FIRST !!!!

This curriculum package will get you started in the area of electricity. Before you say, "I just don't feel comfortable teaching the subject," read through the materials. They are practical, beginner oriented, step-by-step, and briefly written with all the necessary pictorial representations. Prior to curriculum development, my background included several years experience as an electronics technician and residential electrician. And since beginning work in education, I have encountered a recurrent theme regarding instruction in electricity. The basics are all too often taken for granted and infrequently applied to common applications. Teacher preparation is geared to covering the entire realm of electricity/electronics with little attention to instruction at the secondary level. Furthermore, the situation is complicated by the availability of instructional tools. This package addresses these concerns so that more teachers will be inclined to say that, "sure, it's a part of my yearly instruction."

Brian P. Murphy
Curriculum Specialist

CONTRIBUTORS:

Carol Cavanaugh....copy preparation and patience.
Phillip Foster.....schematics.

ACKNOWLEDGEMENT

To John D. Wentz...
an electrician by trade
a teacher by nature

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ELECTRICITY FUNDAMENTALS

ELECTRICITY FUNDAMENTALS

INTRODUCTION

Electricity/Electronics is often the step-child of Industrial Arts and Science classes in the public school. Many teachers avoid this subject area because:

1. Little distinction is made between electricity/electronics.
2. Their teacher preparation lacked adequate course-work in basic electricity fundamentals.
3. Electricity/electronics curricula tend to be very broad in scope, geared to the high school level, and devoid of concept-activity materials.
4. Packaged teaching materials tend to be quite expensive and sophisticated.
5. There is a limited availability of electricity/electronic components centered around instruction.

This package of materials is designed to address these problems and assist the teacher in starting to teach two general areas of electricity--electricity fundamentals and house wiring. The curriculum, activities, and resources are intended for the middle/junior high school level or for beginning classes at the senior high school. It should also be emphasized that these materials are a suggestion, not a prescription, for setting up an electricity course. After using these or similar materials as a start, the teacher can expand the program to suit the specific needs of the students.

GETTING STARTED

First obtain some books on electricity; simple, junior high texts are best. Find books on electricity (check the bibliography in this packet). If new to the subject the teacher should carefully approach any publications with electronics in the content. These books tend to make many assumptions, lean heavily on theory, and become rapidly complex. Much of the confusion and resulting avoidance of electricity stems from these two subject areas being treated as a single topic. The following definitions should help to clarify the issue and provide a point of departure for starting to teach electricity.

ELECTRICITY FUNDAMENTALS

DEFINITIONS

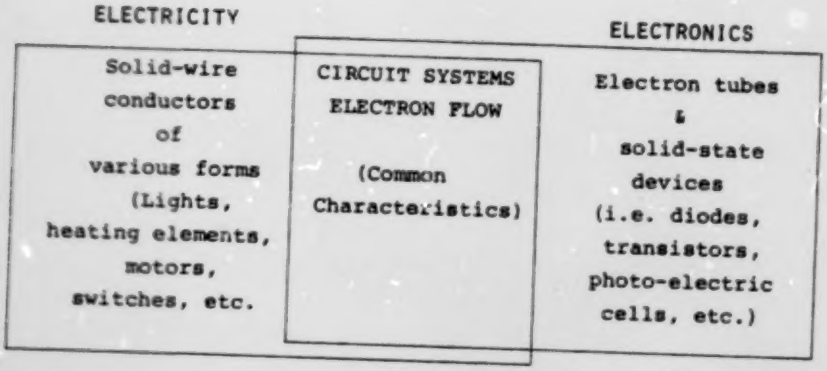
Electricity is defined as...

1. a fundamental entity of nature
2. a form of energy generated by friction, induction, or chemical change
3. consisting of negative and positive states
4. observable in attractions or repulsions of bodies
5. having magnetic, chemical, and radiant effects

Electronics is defined as...

1. a science or branch of physics
2. dealing with the emission, behavior, and effects of electron flow
3. dealing with devices and controls related to electrons

The study of electricity/electronics has the common individual characteristics shown below.


ELECTRICITY
Solid-wire conductors of various forms (Lights, heating elements, motors, switches, etc.
CIRCUIT SYSTEMS
ELECTRON FLOW
(Common Characteristics)
ELECTRONICS
Electron tubes & solid-state devices (i.e. diodes, transistors, photo-electric cells, etc.)

BUILDING KNOWLEDGE

Now that you have books on electricity; read one. Then compare it with the other books. See which illustrations are the clearest and whether or not there are student activities that really get the essential points across. Different authors convey their messages in different manners, especially on this topic. You will often find comparing two or three books a quick and efficient means of clarifying the basic concepts.

As you build your knowledge about electricity, try out an experiment or two, just to check your learning. Since most facets of this subject rely on a few basic principles (i.e. magnetism, current, voltage and resistance), your initial understandings are crucial. Further studies will reveal a gradual refinement and sophistication of simple fundamentals. For example: a car's voltage regulator is simply a coil-operated switch; the coil is operated by magnetism; the magnetism in the wires is caused by current from the generator. If you understand simple electromagnetism, the voltage regulator is no longer a mystery. Junior high students, if properly taught, can understand these principles as well.

Once you are conversant with the basics, look at the curriculum structure in this package. It has been designed to teach simple electricity through activity-oriented steps illustrating single concepts. The curriculum is a context within which to operate, a guide. Each topic has three elements, the subject (concept), activity and the breadboard or materials used by the students. Modify, expand or reduce it to meet your needs.

ELECTRICITY FUNDAMENTALS--CURRICULUM OUTLINE

CONCEPT	ACTIVITY	MATERIALS (BB=Breadboard)
ELECTRICAL SAFETY	Discuss safe and unsafe conditions and dangerous current paths. State rules and procedures for safe laboratory activities. Demonstrate these concepts.	Textbook safety information, handouts, check sheets, etc.
THE SIMPLE CIRCUIT (source, conductor, load)	Assemble a simple circuit with an electrical source, conductor (wires and switch), and load (light). What are the requirements for a simple circuit?	Simple Circuit BB or equivalent
CONDUCTORS/ INSULATORS	Using a simple circuit, place different materials in the path of current flow. Evaluate the results. Which materials conduct or insulate and to what degree?	Conductor-Insulator BB or equivalent
MAGNETISM	Use bar magnets, compasses, iron filings to observe magnetism. Caused by current flow, what is comparatively observed between bar magnets and conductors in producing magnetism?	Bar magnets, card stock, compasses, iron filings and the Magnetic Lines of Flux BB or equiv.
ELECTROMAGNETISM	Using conductors, loops and coils, observe the direction and intensity of magnetism with compasses. Which is strongest and weakest? How does the compass pointer react?	Magnetic Lines of Flux BB or equivalent

ELECTRICITY FUNDAMENTALS--CURRICULUM OUTLINE

CONCEPT	ACTIVITY	MATERIALS
SERIES CIRCUITS	Construct a circuit with series loads and observe the effects of voltage drop, and circuit interruption (by removing one load). What is a series circuit and how does it react?	Series Circuit BB or equivalent
PARALLEL CIRCUITS	Construct a parallel circuit with loads and observe its effects on voltage drop and the removal of one load. How does it differ from a series circuit?	Parallel Circuit BB or evuivalent
PROTECTING CIRCUITS	Construct a parallel circuit with three thermal fuses* of the same value, a common meter, and three different loads (two designed to overload a fuse). What conditions blow the fuse and what happens to the circuit?	Fuse BB or equivalent
MEASURING ELECTRICITY	Using a simple circuit, make the proper connections and measure voltage, current, and resistance. What are the values and their relationships (Ohm's law)?	Textbook safety information, handouts, check sheets, etc.

*NOTE: Circuit breakers may be substituted for thermal fuses.

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ELECTRICITY FUNDAMENTALS--BREADBOARDING

INTRODUCTION

The concept of breadboarding is quite common in teaching electricity/electronics and ranges from instructor prepared to pre-packaged (expensive) teaching modules. Breadboarding simply provides a framework and components for experimentally testing the feasibility of a concept in electricity. For a teacher who is new to teaching electricity, instructor prepared materials can prove to be frustrating because of the many concepts and related hardware required. Furthermore, suppliers generally do not carry inexpensive instructional materials. The following information is intended to address this problem by specifying 1) nine concepts with related breadboards, 2) the hardware necessary to assemble each breadboard, 3) a list of suppliers and 1978 price ranges and 4) the basic teaching concepts related to each breadboard.

POWER SUPPLIES

In order for the breadboard to operate, an electrical source is needed. Again, the teacher is confronted with numerous decisions. Let us address them, one by one. The first consideration should always be student safety. Therefore, a power supply minimizing the chances and severity of electrical shock must be used. Second, the source should be of a common value in volts and amps so that unusual equipment is not required. Third, it is desirable to have a source that is reliable, inexpensive, and designed to withstand potential damage from student error. Power supplies can be purchased from $15.00 to over $250.00 each, or the teacher can build a simple one as illustrated later in this section.

Voltages? Current? AC? DC? Which is best? Probably the most unacceptable source for <u>laboratory experimentation</u> is 110-120 volts AC which is the common system used in house wiring. The chances and severity of electrical shock are far too great for lab work where the current carriers are exposed. Components for lower AC voltages are difficult to find and, besides, the theory of alternating current (AC) in laboratory experimentation is beyond the scope of this curriculum. House wiring is,

however, included but the concepts are confined to installation and operation, not theory.

Which DC voltage and current, then, is desired? Several common voltages are available and include: 1.5 and 3.0 v. (flashlights), 5.0 v. (computers), 12.0 v. (automobiles), and 24.0 v. (military). This curriculum package recommends the 12.0 v. DC system because the voltage is sufficient to produce the effects for each concept. In addition, automotive and 12.0 v. DC components are very common, relatively inexpensive, easily obtained, and can be used to expand an electricity course from this basic curriculum.

As with voltages, different current capacities (amperages) are available. If power supplies are purchased, know the amperage since some lab work depends upon known values. Generally, the lower the amperage, the lower the cost. And, speaking of cost, the most inexpensive route is to build power supplies from scratch. A 500 milli-amp supply is sufficient, costs about $9.00 and can be assembled in about 30 minutes provided everything is at hand. Figure one is a schematic of that supply, figure two, the pictorial representation. This supply may use a regulated output which keeps the voltage constant no matter which load is placed in the circuit. Check the hardware list for parts and prices.

POWER SUPPLY ASSEMBLY

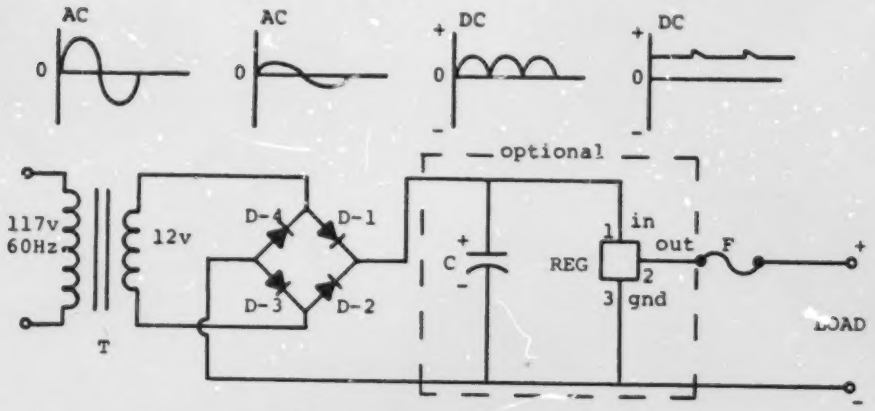
Use this sequence to assemble the power supply.

1. Solder the connections between the transformer-diodes-capacitor*-voltage regulator*-fuse.
2. Drill the necessary holes in the minibox for the line cord, jacks, and transformer.
3. Insert the grommet and line cord (knot the end of the line cord).
4. Install the jacks.
5. Install the soldered component assembly. (Screw or glue in place).
6. Connect the line cord and transformer.
7. Plug in and test.

* Optional components (see page 8).

SCHEMATIC

FIGURE 1



T = Transformer 117 volts Primary, 12.6 volts Secondary

D_1- D_4 = Diodes (or use a bridge rectifier)

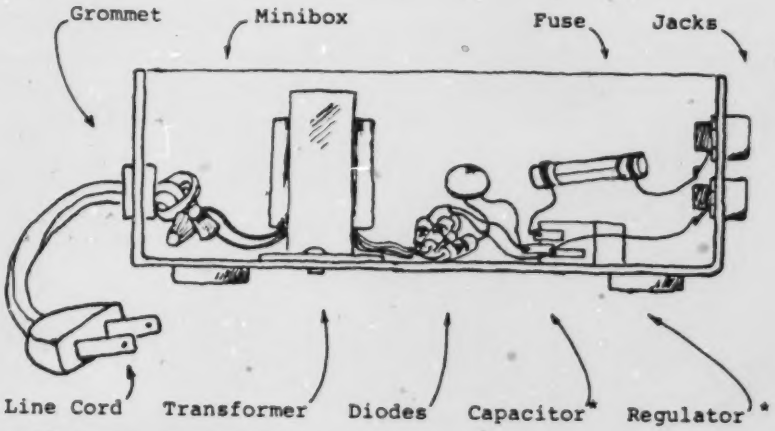
These components are optional for expanding lessons beyond this curriculum where a more controlled power supply is desired, but are not necessary for the concepts outlined in this package.

C = 470 uf 25 volt Capacitor (observe polarity)*

REG = Voltage Regulator*

PICTORIAL

FIGURE 2



* Optional components.

SUPPLIERS

As far as teaching electricity is concerned; there are three basic sources - the instructional and conventional supplier and the manufacturer. Instructional suppliers carry laboratory style equipment and teaching packages and are somewhat more expensive than conventional suppliers. The conventional supplier generally has a wider range of less expensive components from several manufacturers. However, these materials may not be specifically suited to instruction. Manufacturers constitute a direct source but you often find that they will recommend purchasing their materials from a distributor. Most conventional suppliers are happy to assist in gathering these materials. Once the required hardware has been determined, these and other sources may be contacted.

This is the supplier code of manufacturers and instructional suppliers used with the hardware list: (conventional suppliers are <u>not</u> present in the code but do carry most of the needed materials and are listed in this section).

BG - Broadhead-Garret
BM - Bussmann Manufacturing
CL - Calectro
CM - Chicago Miniature
ES - Essex Stancor
AC - AC Electronics
GH - Graves-Humphreys
IA - Industrial Arts Supply Company (IASCO)
KS - Keystone Electronics
LF - Littlefuse
LS - Local Supplier (i.e. hardware, lumber yard, etc.)
OH - Ohmite
PE - Pamona Electronics
SH - Shurite
SO - Sola
SY - Sylvania
TM - Thordarson Meissner
TR - Triplett
TU - Triad-Utrad

These are the instructional suppliers:

Broadhead-Garret
4560 East 71st Street
Cleveland, Ohio 44105
(216) 341-0248

Graves-Humphreys, Inc.
P. O. Box 13407
1948 Franklin Road
Roanoke, Virginia 24033
(703) 343-8011

Industrial Arts Supply Company (IASCO)
5724 West 36th Street
Minneapolis, Minnesota 55416
(612) 920-7393

These are the conventional suppliers in the Washington-Baltimore areas. They are by no means the only suppliers. Checking the yellow pages of your phone directory under "Electronic Equipment and Supplies - Retail or Wholesale" will provide information on local resources.

Henry Berman company
12 East Lombard
Baltimore, Maryland 21202
(301) 539-7002

Capitol Radio Wholesalers (Highly Recommended)
12270 Wilkins Avenue
Rockville, Maryland 20852
(301) 881-2270

Lafayette Radio Electronics
(Check your local listings)

Measurement Shop
2 West 22nd Street
Baltimore, Maryland 21218
(301) 235-1746

McCourt Company
9070 Chevrolet Drive
Ellicott City, Maryland 21043
(301) 937-4030

Radio Shack
(Check your local listings)

A. R. Spartana Co.
239 N. Gay Street
Baltimore, Maryland 21202
(301) SA 7 - 0484

United Electronics
207 South Central Avenue
Baltimore, Maryland 21202
(301) 732-5000

Whitney Distributing
6707 White Stone Road
Baltimore, Maryland 21207
(301) 944-8000

ELECTRICITY FUNDAMENTALS--HARDWARE

ITEM	SUPPLIER CODE	PRICE RANGE AVERAGE
ammeter, DC, 500 ma	CL, TR, SH	$ 6.00
aluminum, strip, 3/8" w (approx.)	LS	-
board, shelving, pine	LS	-
bolt, round head, slotted, 1/4 - 20, 1"	GC	.05
+ box, mini or hand, 2" x 4" (approx.)	CL	2.50
brass, strip, 3/8" w (approx.)	LS	-
buzzer, DC	IA, CL	1.00
+ capacitor, 500 uf, 25 v.	CL	.20
card stock (index)	LS	-
coil compound	GC	1.50
compass, 1" dia. (approx.)	IA, BG	.50
connector, wire, solderless, small	CL, GH, BG	1.50/100
+ cord, line, AC, 6' (approx.)	CL, ES	1.50
cord, patch, banana plug, 12 - 18"	PE,BG	1.50
*+ diode, 1 amp, 25 v.	KS, IA	.10
dowel, wood	LS	-
filings, iron	LS	-
fuse, 3AG, 1/2 amp	CL, LF, BM	.15
fuseholder, 3 pole, 3AG	KS, LF, BM	1.90
glass, strip	LS	-
+ grommet, rubber, 1/4 - 3/8 (approx.)		.10
hardboard, tempered, 1/8"	LS	-
jack, banana	GC, PE, BG	.20
lamp, miniature, screw base, 12 v. DC	CL, SY, CM, GH	.40
lead, test, 24", with probe and banana plug	GC, PE, BG, GH	2.75
motor, DC, simple open construction	IA, GH	1.50
nut, square or hexagonal, 1/4 - 20	GC	.02
power supply, 500 milliamp, 12 v. DC	SO, BG, GH, IA	(see text)
regulator, voltage	CL	1.50
resistors, assorted	GC, OH	.15
socket (receptacle) miniature, screw base, surface mount	CL, CM, GH	.35
spacer, round, 1/2"	GC	.20
switch, knife, single pole, single throw	CL, BG, IA	.45

ELECTRICITY FUNDAMENTALS--HARDWARE

ITEM	SUPPLIER CODE	PRICE RANGE AVERAGE
*+ transformer, filament, 117 v. primary, 12 v. secondary, 1 amp	CL, ES, TU, TM, IA	$ 2.00
wire, copper, bare, 12 ga.	LS	-
wire, hook-up, insulated, 20 ga. (approx.)	CL, ES, BG, IA	5.00/100
wire, nichrome, 20 ga. (approx.)	IA, BG	6.75/100

* NOTE: Transformers with built-in rectifiers are also available.

+ Power supply items.

ELECTRICITY FUNDAMENTALS--THE BASIC BREADBOARD

WHY?

The basic breadboard is a simple box; simple to use, simple to make. Why use this method as opposed to others? These reasons may answer that question:

1. The boxes are relatively inexpensive as breadboards go.
2. They can be stacked to minimize needed storage space.
3. Components are securely fastened and protected from damage.
4. The student's activities are centered on the box and not all over the workbench.
5. Most of the current carriers can be wired on the back of the box.

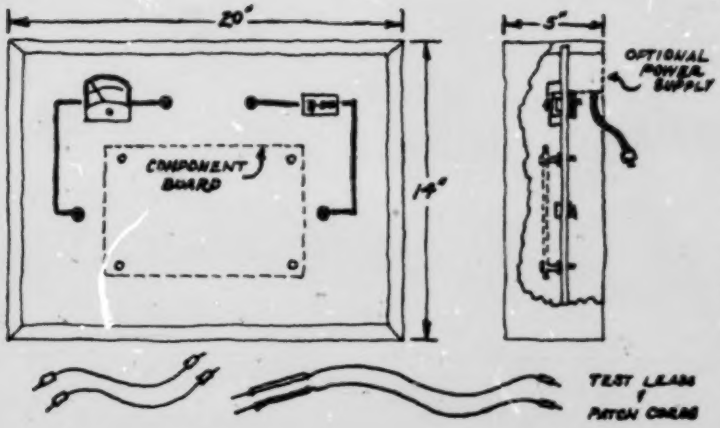
DESCRIPTION

Refer to the next page as your read this description. The box consists of a hardboard panel set into the dado of a pine frame. A suggested size is 14" x 20". The face is inset approximately 3" and contains the ammeter, knife switch, four banana jacks, and four holes (to accept the alignment bolts on each component board). You can wire on the back side but paint or tape lines showing the conductors on the face to help the students' understanding. The back side is inset to protect the jack terminals and meter movement. You could also attach a small power supply to the back. If that is done, still use patch cords from the power supply to the circuit so the students understand that the source is a separate entity within the circuit. Paint and/or stain the wood. When something looks nice, chances are it will be treated nice.

ELECTRICITY FUNDAMENTALS--THE BASIC BREADBOARD

SCHEMATIC

PICTORIAL



PARTS

1....ammeter, 500 milliamps
1....board, shelving, pine, 68" (approx.)
2....cord, patch, banana plug, (1 red, 1 black)
1....hardboard, tempered, 1/8", 14" x 20" (approx.)
4....jack, banana, (2 red, 2 black)
2....lead, test, 2', with probe and banana plug, (1 red, 1 black)
1....switch, knife, single pole, single throw
1....wire, hook-up, insulated, 20 guage (approx.), random length

TEACHING CONCEPTS

This basic breadboard forms the heart of a system using interchangeable components to teach electricity fundamentals.

ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENTS

Each component teaches a simple concept or two. It is "plugged into" the basic breadboard by aligning the four bolts and dropping the component board into place. Two patch cords are then used to complete the circuit from component to breadboard. Make sure that the four aligning bolts have some sort of spacers to prevent the hardware on the back of each component (i.e. banana jacks) from hitting the face of the breadboard. As with the basic breadboard; the schematic, pictorial, parts and teaching concepts are present.

Special Note: The following concepts require a load resistor in series to prevent the component from acting as a short circuit, thus blowing the power supply fuse: Magnetic Lines of Flux, Conductor Magnetism, Fuses, and Electrical Loads--Light & Heat. For these concepts you will be using components of the same voltage (E) as the power supply.

RESISTANCE VALUES To calculate resistor values.....

1. Know the maximum amperage (I) of the transformer.
2. Divide the voltage by the amperage for the value in resistance. For example.....
   (12.6 volt, .5 amp transformer secondary)
   $\frac{E}{I} = R$ or $\frac{12}{.5} = 24$ ohms resistance

VOLTAGE CHANGES For Electrical Loads--Sound & Motion or other components of a different voltage from the power supply.....

1. Construct a circuit with an ammeter in series, the component and a voltage source of the same value. Measure the current flow (the breadboard meter can be used) to determine the amperage.
2. Calculate the resistance values as in step #2 above.

WATTAGE For either method above, you must also calculate wattage (power) to know the necessary resistor wattage. To do this:

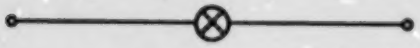
1. Multiply the voltage times the amperage. For example....
   E I = P or 12 (.5) = 6 watt resistor size.

Remember that the variables $\frac{E}{I} = R$ and $P = IE$ can be used in different combinations for the desired values. Also remember that for resistance values, you must subtract the component resistance for the actual resistor value desired. Try it. It's not difficult at all!

ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENTS

SIMPLE CIRCUIT

SCHEMATIC



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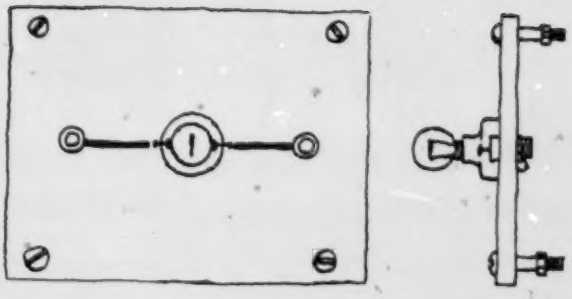


PARTS

4 bolt, 1/4 - 20
1 hardboard, tempered
2 jack, banana, (1 red, 1 black)
1 lamp, miniature
4 nut, 1/4 - 20
1 socket, miniature
4 spacer, 1/2"
1 wire, hook-up, (as needed)

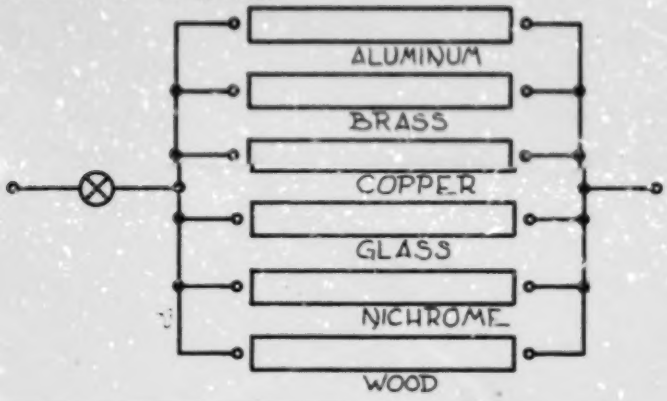
TEACHING CONCEPTS

* source, conductor, load
* complete circuit
* current flow
* polarity

ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENTS

CONDUCTORS--INSULATORS

SCHEMATIC



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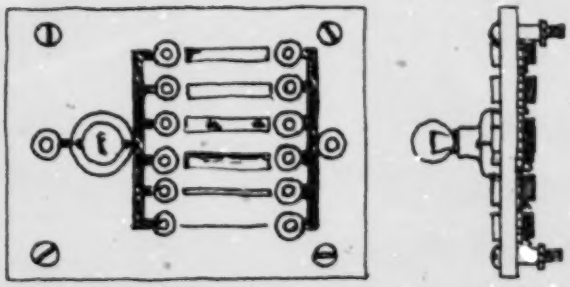


PARTS

1	aluminum, strip
4	bolt, 1/4 - 20
1	brass, strip
1	dowel, wood
1	hardboard, tempered
1	glass, strip
14	jack, banana (7 red, 7 black)
1	lamp, miniature
4	nut, 1/4 - 20
1	socket, miniature
4	spacer, 1/2"
1	wire, copper, bare, 12 ga., 4" (approx.)
1	wire, hook-up, (as needed)
1	wire, nichrome, 4" (approx.)

CONDUCTORS--INSULATORS (Continued)

TEACHING CONCEPTS

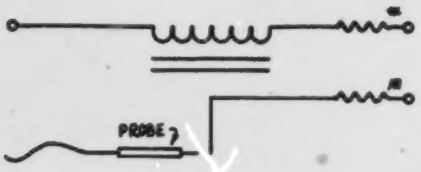
The simple circuit plus.....

* conductors and non-conductors (insulators)
* conductor capacity and conductivity

ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENTS

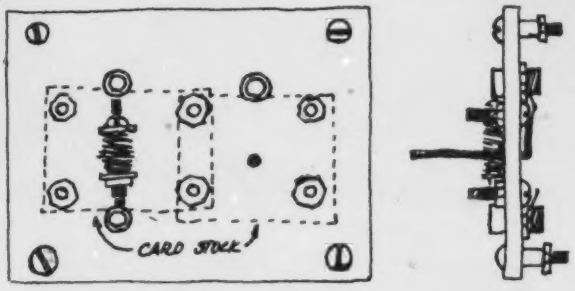
MAGNETIC LINES OF FLUX

SCHEMATIC



* see page 16 "Resistance Values"

PICTORIAL



PARTS

10 bolt, 1/4 - 20
1 card stock
1 coil, iron core
(To construct: Use a carriage bolt, nut and washer. Wrap bare hook-up wire around the bolt between the head and nut until the space is filled. Leave a lead on each end, attach to the circuit and paint the windings with coil compound.
2 compass
1 filings, iron
1 hardboard, tempered
3 jack, banana (1 red, 2 black)
10 nut, 1/4 - 20
2 resistors, assorted
10 spacer, 1/2"
1 wire, copper

MAGNETIC LINES OF FLUX (Continuted)

1 wire, copper, bare, 12 ga., 6" (approx.)
1 wire, hook-up (as needed)

TEACHING CONCEPTS

The simple circuit plus.....

* magnetism-electromagnetism
* magnetic lines of flux
* relationship of current flow direction to lines of flux

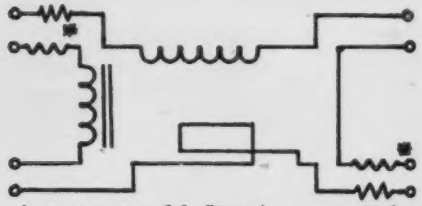
Special Note: A resistor must be placed in series for both the coil and the conductor. See page 16 for determining the proper values in resistance and wattage. After figuring the resistance values, measure and subtract the resistance of the coil and conductor for the actual resistor values needed.

This experiment is designed to illustrate magnetic lines of flux by using iron filings sprinkled on card stock. The bolts are intended to support the card stock while the circuit is energized. The right hand conductor must have a test probe connected to the top end for a current path. Naturally the card stock will require a hole punched in the center to place it over the conductor.

ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENTS

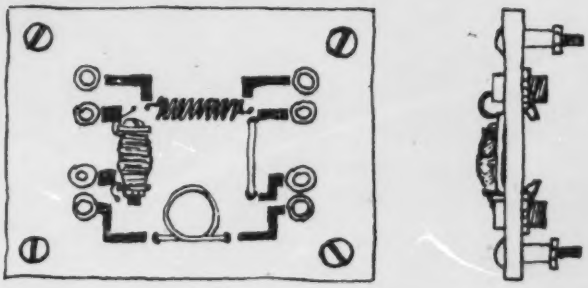
CONDUCTOR MAGNETISM COMPONENT

SCHEMATIC



* see page 16 "Resistance Values"

PICTORIAL



PARTS

4 bolt
1 coil, air wound
(To construct: Using bare hook-up wire; wrap the wire around a wood dowel, remove the dowel and mount the coil on the board.)
1 coil, iron core
(To construct: See the Magnetic Lines of Flux Component.)
1 compass
1 hardboard, tempered
8 jack, banana (4 red, 4 black)
4 nut, 1/4 - 20
2 resistors, assorted
4 spacer, 1/2"
1 wire, copper, bare, 12 ga.

CONDUCTOR MAGNETISM COMPONENT (Continuted)

1 wire, hook-up (as needed)
1 wire loop, copper, bare, 12 ga.

TEACHING CONCEPTS

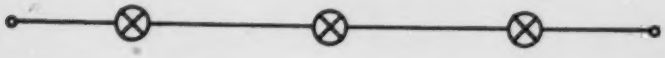
The simple circuit plus.....
* magnetic lines of flux
* relationship of magnetic lines and current flow
* compounding magnetism with coils and cores

Special Note: A resistor must be placed in series on two of the diagonally opposed jacks. See page 16 for determining the proper values in resistance and wattage. After figuring the resistance values, measure and subtract the resistance of the straight conductor and the air wound coil for the actual resistor values needed.

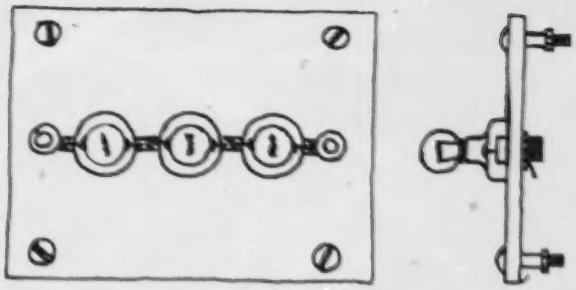
ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENT

SERIES CIRCUIT

SCHEMATIC



PICTORIAL



PARTS

4 bolt, 1/4 - 20
1 hardboard, tempered
2 jack, banana, (1 red, 1 black)
3 lamp, miniature
4 nut, 1/4 - 20
3 socket, miniature
4 spacer, 1/2"
1 wire, hook-up, (as needed)

TEACHING CONCEPTS

The simple circuit plus.....

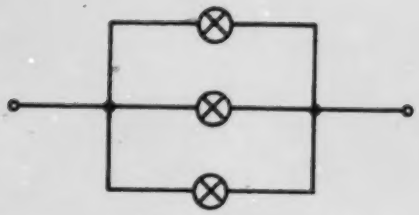
* series loads
* voltage drop (apparent in the intensity of illumination)
* incomplete circuit (by removing 1-2 lamps)

24

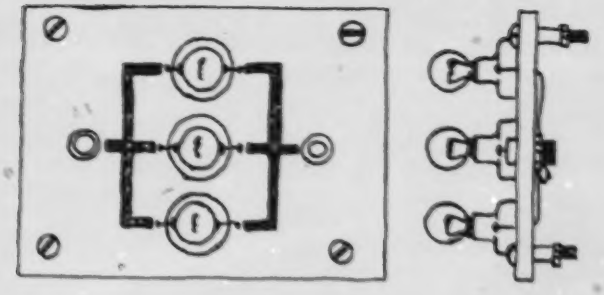
ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENT

PARALLEL CIRCUIT

SCHEMATIC



PICTORIAL



PARTS

4 bolt, 1/4 - 20
1 hardboard, tempered
2 jack, banana (1 red, 1 black)
3 lamp, miniature
4 nut, 1/4 - 20
3 socket, miniature
4 spacer, 1/2"
1 wire, hook-up, (as needed)

TEACHING CONCEPT: The simple circuit plus.....

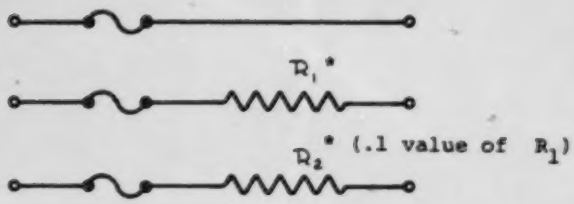
* parallel loads
* constant voltage (apparent in the intensity of illumination)
*complete circuit (even with the removal of 1-2 lamps)

25

ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENTS

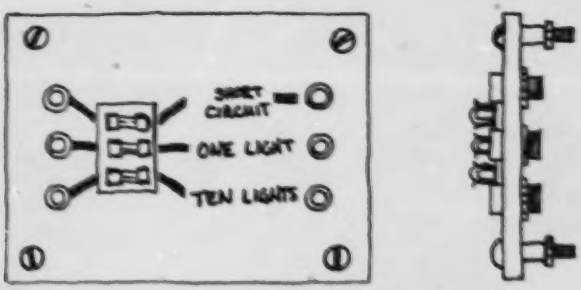
FUSES

SCHEMATIC



* see page 16 "Resistance Values"

PICTORIAL



PARTS

4 bolt, 1/4 - 20
3 fuse, 3AG, 1/2 amp
1 fuseholder, 3 pole, 3AG
(circuit breakers may be substituted for fuses)
1 hardboard, tempered
6 jack, banana, (3 red, 3 black)
4 nut, 1/4 - 20
2 resistor, assorted
4 spacer, 1/2"
1 wire, hook-up, (as needed)

TEACHING CONCEPTS

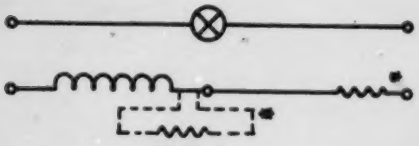
The simple circuit plus.....

* the relationship of current to load
* fuse operations-open circuits
* conditions for overloaded circuit

ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENTS

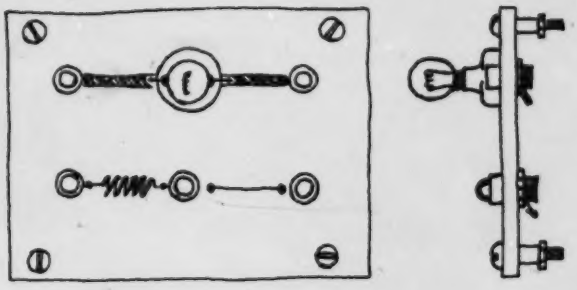
ELECTRICAL LOADS
LIGHT & HEAT

SCHEMATIC



* see page 16 "Resistance Values"

PICTORIAL



PARTS

4 bolt, 1/4 - 20
1 coil, air wound
(To construct: For the left-hand air wound nichrome coil; wrap the wire around a wood dowel, remove the dowel and mount the coil.)
1 hardboard, tempered
5 jack, banana (3 red, 2 black)
1 lamp, miniature
4 nut, 1/4 - 20
1 socket, miniature
4 spacer, 1/2"
1 wire, hook-up, (as needed)
1 wire, nichrome, (as needed)

ELECTRICAL LOADS
LIGHT & HEAT (continued)

TEACHING CONCEPTS

The simple circuit plus.....

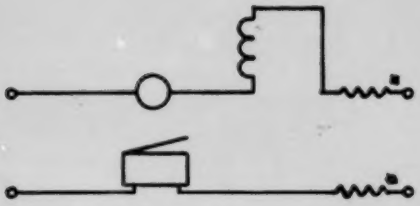
* conditions for light (resistance in a vaccuum)
* conditions for heat (high resistance)
* means of varying amounts of heat

Special Note: Resistors must be placed in series on the nichrome wires. Depending upon the total resistance of the nichrome wire coil, a resistor may or may not be necessary. See page 16 for determining the proper values in resistance and wattage. After figuring the resistance values, measure and subtract the resistance of the nichrome straight wire and coil for the actual resistor values needed.

ELECTRICITY FUNDAMENTALS--BREADBOARD COMPONENTS

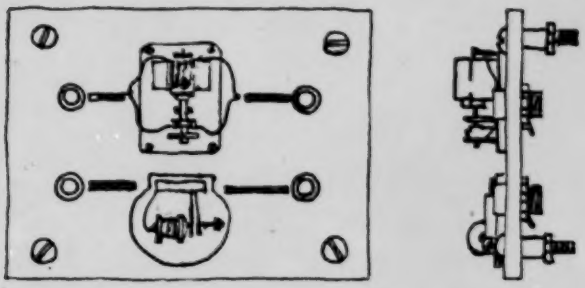
ELECTRICAL LOADS -
SOUND & MOTION

SCHEMATIC



* see page 16 "Voltage Changes"

PICTORIAL



PARTS

4 bolt, 1/4 - 20
1 buzzer, DC (open construction)
1 hardboard, tempered
4 jack, banana (2 red, 2 black)
1 motor, DC (open construction)
4 nut, 1/4 - 20
2 resistor, (step-down, 12 to 3 VDC)
4 spacer, 1/2"
1 wire, hook-up (as needed)

TEACHING CONCEPTS The simple circuit plus.....

* conditions for motion
* conditions for sound
* magnetism

HOUSE WIRING

HOUSE WIRING

INTRODUCTION

Although the second part of this curriculum, the House Wiring section can be taught separately. Consequently, the curriculum, hardware, suppliers and teaching aids are all kept within this section. Different considerations must also be made for teaching house wiring, especially in the areas of safety and theory.

SAFETY AND THEORY

Safety is crucial since the voltage and current involved presents the possibility of harmful electrical shock. This is not to say house wiring cannot be safely taught; it is to say that close supervision and procedures are required on the part of both teachers and students. By instilling the primary need for safety (through instruction in house wiring) the students will ultimately benefit by knowing and understanding potential electrical hazards in their own homes. Most safety rules can be obtained from any text on the subject, however, the following points should be ever-present in the teacher's mind:

1. Installation of conductors and devices should always be performed in the absence of an electrical source.
2. Any operations performed by students should be carefully inspected by the teacher.
3. The teacher should connect and charge the source.
4. Students should clearly understand that their own homes are not to be used for experimentation and that the same hazards are present in both settings.

As far as theory is concerned, alternating current is beyond the scope of this curriculum. However, the installation and operation of simple house wiring circuits is within its domain. Initial student understanding can be most easily facilitated if the electricity fundamentals in the previous half of this curriculum are taught first. Should house wiring alone be taught, the student will need to understand these prerequisite concepts:

HOUSE WIRING

1. source, conductors/insulators, loads
2. the simple circuit
3. switch operation
4. the parallel circuit

These topics are addressed in the house wiring section and are essentially the same as in the electricity fundamentals section.

GETTING STARTED

If you read the electricity fundamentals section, this approach in starting to teach house wiring will look similar. A rudimentary knowledge of electricity basics is a prerequisite for this section. Obtaining books on house wiring is the first step. Practical, hands-on books are best since the curriculum in this section addresses installation and operation. You need not know the theory of alternating current or the more sophisticated aspects of residential electrical systems to teach these materials. Look for highly illustrated books with clear pictorial drawings. These publications are common and available in handyman "how-to" or text versions. Avoid books that closely adhere to specific building codes or are so comprehensive that the bulk of the text is beyond simple house wiring.

Once you have two or three books to compare, read one. Check the clarity of the illustrations; they should be primarily pictorial representations. Schematic drawings are helpful but are quite often different from the actual installation. Color pictorials are also desirable because different color insulators are used. However, do not panic if you discover slightly different color coding from book to book. This is more a function of regional practice or personal preference by individual electricians.

In becoming familiar with house wiring, establish in your mind the relationships between circuits and devices. Most house wiring entails supplying and controlling 110 or 220 volts AC to simple loads (i.e. light, heat, sound, and motion). Basically, simple switches operate lights,

heating elements, fans, etc. Beginning students can easily understand these concepts once the installation of devices is understood. Just remember safety in every step.

When you become comfortable with simple house wiring concepts, examine the curriculum in this section. As with the previous section on electricity fundamentals, it is designed with activity-oriented steps illustrating single concepts. Each topic contains three elements; the subject (concept), the activity and the wiring frame exercise. You can easily expand this basic curriculum to any degree of sophistication desired.

SPECIAL NOTE: As you begin to work with wiring devices, you will soon see a wide variation in the ways in which conductors are attached. Do not become too concerned about these inconsistencies and follow this one universal rule. Regardless of the location of a terminal on a device....

* the green hexagonal screw is ground
* the white round screw is neutral (white)
* the bronze round screw is hot (black)
* the red round screw is common (red on 3-way circuits)

HOUSE WIRING--CURRICULUM OUTLINE

CONCEPT	ACTIVITY	MATERIALS
ELECTRICAL SAFETY	Discuss the proper procedures for working with 110-220 v. AC: dangerous current paths and conditions, tool usage, determining and testing live circuits, safety clothing, and electrical hazards. Demonstrate unsafe conditions.	Textbook safety information, procedure lists, check lists, etc.
SOURCE-CONDUCTOR LOAD	Discuss the house wiring concepts of an electrical source (service entrance), conductors (wire and cable), and loads (lights, heaters, motors, etc.) Illustrate the nature of this concept by individual examples.	Pictures, examples, chalkboard diagrams.
THE SIMPLE CIRCUIT	Assemble a simple circuit with an electical source, conductor, and load. Show by example and schematic the requirements for a simple circuit.	Simple Circuit breadboard or equivalent (See Electricity Fundamentals).
THE PARALLEL CIRCUIT	Construct a parallel circuit with loads; discuss its effects on voltage drop and the installation and removal of loads in the circuit.	Parallel Circuit breadboard or equivalent (See Electricity Fundamentals).
DUPLEX RECEPTACLES	Using conventional devices and conductors, install and operate two parallel duplex receptacles in a simulated wall space.	Wiring Frame Duplex Receptacles Exercise or equivalent, schematics, examples, etc.

HOUSE WIRING--CURRICULUM OUTLINE

CONCEPT	ACTIVITY	MATERIALS
ELECTRICAL LOADS - LIGHT	Using conventional devices and conductors, install and operate an incandescent lamp; demonstrate the conditions for light (i.e. resistance, vaccuum, heat) and connect or illustrate different lighting sources.	Wiring Frame and unswitched porcelain receptacle or equivalent, lighting fixtures, schematics, etc.
THE SWITCHED LIGHT	With conventional equipment, install and operate a switched light. Clearly demonstrate feed points and how the "hot" side should be switched for safety. Show how the switch interrupts the circuit.	Wiring Frame Switched Light Exercise or equivalent and schematic.
THE SWITCHED RECEPTACLE AND LIGHT	Using the switched light circuit, add a duplex receptacle and teach the same basic concept.	Wiring Frame Switched Receptacle and Light Exercise or equivalent and schematic.
THE 3-WAY SWITCHED LIGHT	NOTE: [This circuit, although quite common, is comparatively sophisticated to the the other activities in this curriculum.] With standard components, install and operate a 3-way circuit. Closely relate the schematic and pictorial/actual components.	Wiring Frame 3-Way Switched Light Exercise or equivalent.
ELECTRICAL LOADS - HEAT	Using a switched duplex receptacle and light circuit, install and operate heating elements (i.e. sun lamp, hair	"How-to" books, public utility resources, and common electrical equipment.

HOUSE WIRING--CURRICULUM OUTLINE

CONCEPT	ACTIVITY	MATERIALS
	dryer, space heater). Demonstrate the conditions for heat.	
USING ELECTRICITY AND ITS COSTS	Refer to the resources section and select materials and services appropriate to the consumption, conservation, and costs of electricity.	Public utility resources.
HOME REPAIRS	Refer to the resources section for information. Discuss and demonstrate common repairs and associated safety with items such as appliances, outlets, receptacles, and switches. Promote the proper care and use of electrical equipment.	"How-to" books, public utility resources, and common electrical equipment.

HOUSE WIRING--THE WIRING FRAME METHOD

INTRODUCTION

The wiring frame serves as the heart of a system wherein many different house wiring exercises may be performed. Regardless of the configuration, house wiring has the common elements of outlet boxes for devices and conductor pathways. Simulation of an actual wall space can be easily facilitated by wiring-in devices and covering the frame with paneling. Students will then understand how electrical service is distributed within a house. Instruction, however, should not necessarily be confined only to the frame. Instruction can include other aspects of house wiring such as kilowatt hour meters, fuse boxes, circuit breakers, 220 v. service, and blueprint reading and planning.

SUPPLIERS

House wiring supplies are considerably more common than components for laboratory experimentation in electricity. Consequently, they are much easier to obtain. The local electrical supply house, hardware store, or lumberyard should have every component needed for this section of the curriculum. In addition, instructional suppliers carry these materials. You may also want to contact some of the major manufacturers for more information and possibly samples.

HOUSE WIRING--HARDWARE

ITEM	PRICE RANGE AVERAGE
box, outlet, 4" square, 1 and 1/2" deep, 1/2" knockouts	$ .50
box, utility, 1/2" knockouts	.50
cable, non-metallic sheathed (Romex), 12/3 with ground	.10/ft.
conduit, thinwall (EMT), 1/2"	1.30/10'
connector, clamping (BX, Romex), 1/2"	.12
connector, thinwall (EMT), 1/2", screw or compression type	.10
connector, wire, solderless, screw-type, large (3M, Red)	3.00/100
connector wire solderless, screw-type, small (3M, Yellow)	2.65/100
cord, line, 12/ with ground (flexible rubber or equivalent)	.25/ft.
cover, switch, single, metal or plastic	.30
cover, duplex receptacle, metal or plastic	.30
nut, wing, 1/4 - 20	.10
outlet, porcelain, keyless	.68
plug, 3 wire, with ground pin	.60
receptacle, duplex, grounding-type	.50
ring, plaster (adaptor), 4" square to round	.30
ring, plaster (adaptor) 4" square to single gang	.30
screw, grounding	.05
screw, wood, round head, 1"	.10
stud, machine-wood screw, 2"	.20
switch, fused, with plate (utility box)	2.00
switch, single pole, single throw	.79
switch, 3-way	.98
washer, flat, 1/4" diameter hole, 1/2"	.05
wire, non-metallic sheathed (Romex), 12/3 with ground	.10/ft.
wood paneling, 1/8"	-
wood, studding, 2" x 4"	-

HOUSE WIRING--THE WIRING FRAME

INTRODUCTION

The wiring frame simulates an actual wall space with top and bottom plates, studs 16" on center, and a paneling cover. Three 4" square boxes are set to accept common devices and are large enough for a variety of wiring configurations. Although most homes are wired between boxes with non-metallic sheathed cable (NM/Romex), conduit is used in this frame. Using thinwall conduit (EMT/Electrical Metallic Tubing) permits students to run any combination of conductors for wiring exercises. Notice that the total length of all three conduits is approximately the same. This way a supply of common length conductors may be cut. They can be used repeatedly to reduce wasted wire.

ASSEMBLY

Assembly of the frame should be accomplished in this sequence:

1. Cut the 2 x 4's to length and drill the necessary holes in the center stud.
2. Securely nail the pieces together and attach the base supports.
3. Bend the two elbows for the conduit. You will need either an electrician's bender or will have to have your supplier do the bending.
4. After the elbows are bent, cut the conduit to the needed lengths. A hack saw will do the job. De-burr the cuts.
5. Attach the connectors to the conduit.
6. Remove the necessary knock-outs from the boxes.
7. Slip the conduit through the center stud holes and attach the connectors to the boxes. Temporarily fasten the plaster rings in place.
8. Pivot the assembly into position and align the boxes. Make sure that the plaster ring protrudes just enough to be flush with the face of the paneling.
9. Mark the attach points for the boxes and remove the plaster rings.
10. Screw, do not nail, the boxes to the studs.

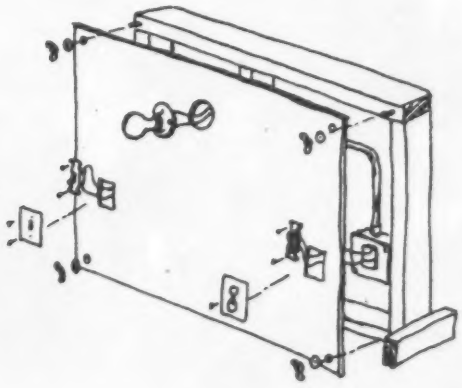
Nails will eventually work themselves out in this situation.

11. Set the four corner studs on the frame. Get the machine/screw type that are used to hold down toilets.
12. Cut the paneling to size; drill holes for the studs; and cut out a round hole for the top box, square (single gang) holes for the two lower boxes.

When the frame is in use, the following procedure is followed:

1. Install the conductors and wire-in the devices.
2. The instructor inspects the work and connects the line cord.
3. Set the plaster rings and paneling in place.
4. Fasten the devices and set the covers.
5. Plug in and charge the line cord.

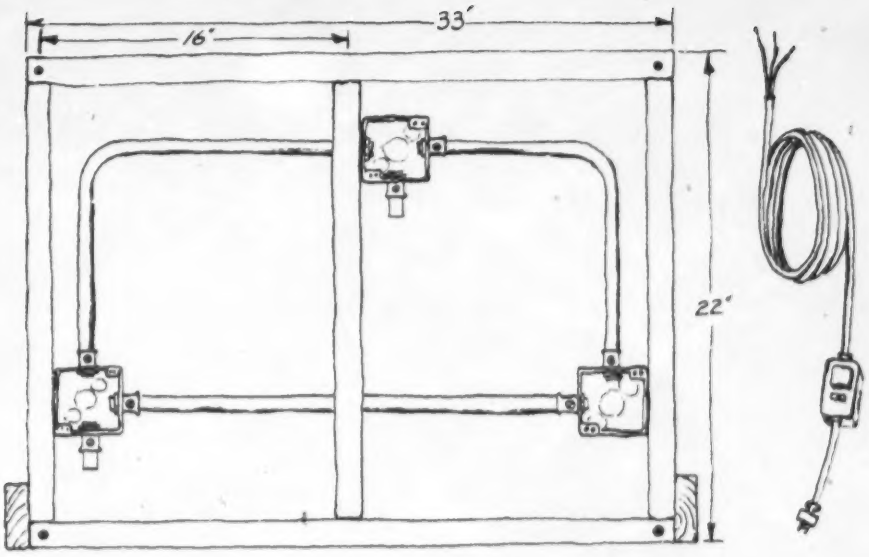
The pictorial below illustrates the assembly of the frame and cover paneling. Note how the devices are brought through the paneling and how wing nuts are used to secure the assembly.



HOUSE WIRING

THE WIRING FRAME

PICTORIAL



PARTS

3 box, outlet, 4" square
1 box, utility
1 conduit, thin wall (EMT), 1/2" x 10'
2 connector, clamping (BX, Romex), 1/2"
8 connector, thin wall, 1/2"
1 cord, line 12/2 w/ground, 20'
1 nut, wing, 1/4 - 20
1 plug, 3 wire
3 screw, grounding
6 screw, wood, round head
4 stud, machine - wood screw
1 switch, fused, with plate
4 washer, flat
1 wood, paneling, 1/8" x 22" x 33"
2 wood, studding, 2" x 4" x 8'

TEACHING CONCEPTS

This house wiring frame forms the basis for teaching simple house wiring installation and operation. Interchangeable devices and conductors can be used for a variety of wiring configurations.

HOUSE WIRING--WIRING FRAME EXERCISES

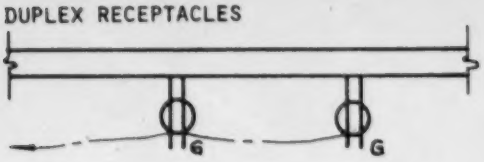
The wiring frame exercises included in this section are a start. They illustrate some of the basic concepts associated with residential electrical systems. Installation and operation of devices, done safely and correctly, are stressed. The components are common-use items and not designed for laboratory experimentation.

Each exercise contains the architectural and schematic presentations, the pictorial representation, the needed parts and the teaching concepts. All parts may be used repeatedly.

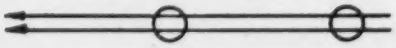
HOUSE WIRING--WIRING FRAME EXERCISES

DUPLEX RECEPTACLES

SCHEMATIC

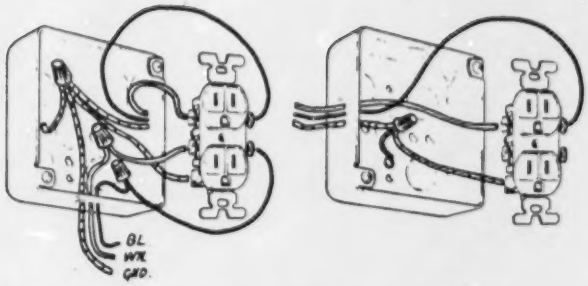


ARCHITECTURAL PRESENTATION



SCHEMATIC PRESENTATION

PICTORIAL



PARTS

4 connector, wire, solderless (yellow)
1 cord, line
2 cover, duplex receptacle
2 receptacle duplex
2 ring, plaster, 4" square to single gang
1 ea. wire, 12 ga. (black, white, bare), 36"

TEACHING CONCEPTS

* parallel circuits
* conductors and grounding
* installation and use

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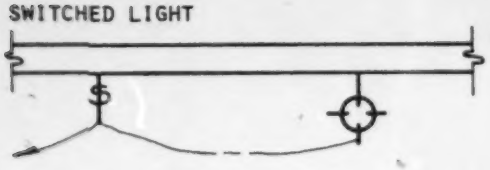
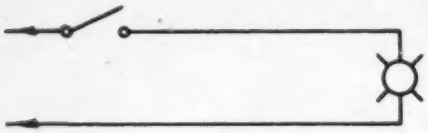
HOUSE WIRING--WIRING FRAME EXERCISES

SWITCHED LIGHT

SCHEMATIC

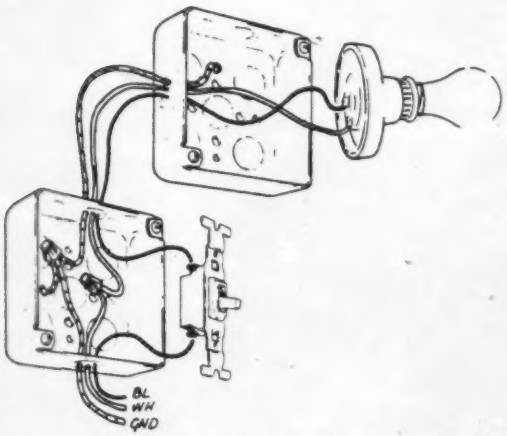


ARCHITECTURAL PRESENTATION



SCHEMATIC PRESENTATION

PICTORIAL



PARTS

4	conncetor, wire, solderless (yellow)
1	cord, line
1	cover, switch
1	outlet, porcelain (with bulb)
1	ring, plaster, 4" square to round
1	ring, plaster, 4" square to single gang
1	switch, single pole
1 ea.	wire, 12 ga (black, white, bare), 36"

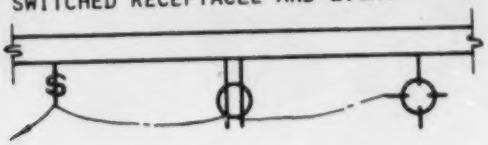
TEACHING CONCEPTS

* circuit interruption by switch
* conductors and grounding
* installation and use
* anything beyond switching point affected by switch

HOUSE WIRING--WIRING FRAME EXERCISES

SWITCHED RECEPTACLE AND LIGHT

SCHEMATIC



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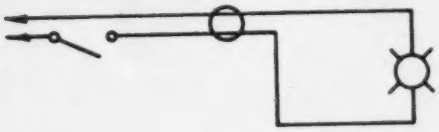
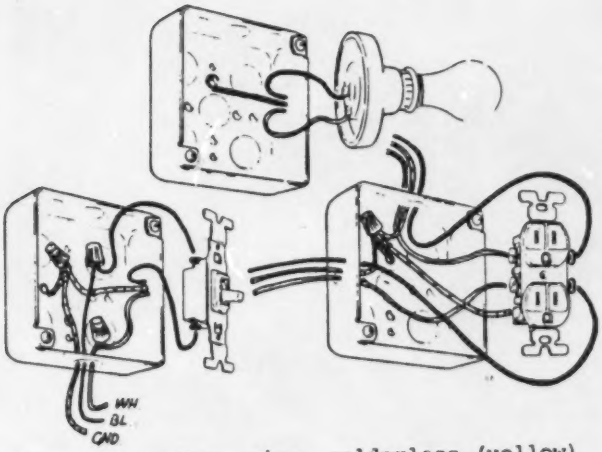


SCHEMATIC PRESENTATION

PICTORIAL



PARTS

6	connector, wire, solderless (yellow)
1	cord, line
1 ea.	cover (switch, duplex receptacle)
1	outlet, porcelain
1	receptacle, duplex
1	ring, plaster, 4" square to round
2	ring, plaster, 4" square to single gang
1	switch, single pole
2 ea.	wire, 12 ga (black, white, bare), 36"

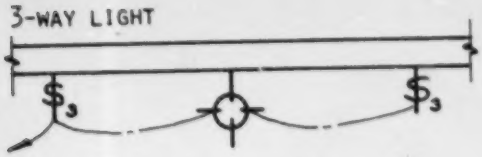
TEACHING CONCEPTS

The switched light plus...

* anything beyond the switching point is affected by the switch

HOUSE WIRING--WIRING FRAME EXERCISES

SCHEMATIC



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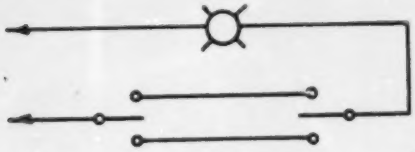
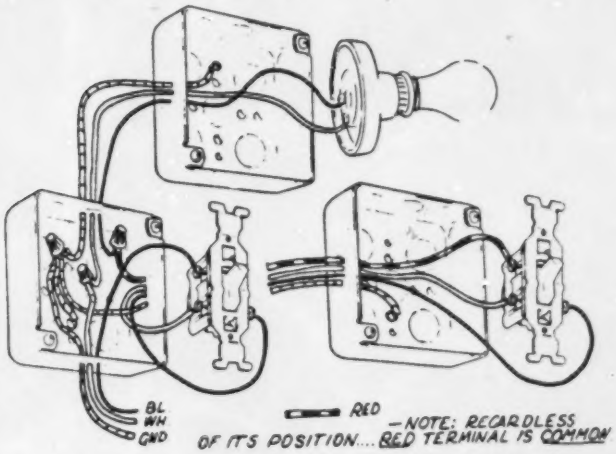


SCHEMATIC PRESENTATION

PICTORIAL



PARTS

6	connector, wire, solderless (yellow)
2	connector, wire, solderless (red)
1	cord, line
2	cover, switch, single
1	outlet, porcelain
1	ring, plaster, 4" square to round
2	ring, plaster, 4" square to single gang
2	switch, 3-way
2 ea.	wire, 12 ga. (black, red, white, bare), 36"

TEACHING CONCEPTS The switched light plus...

* control of a load from two points
* double pole switching

RESOURCES

TEXTS

Baker, G. E. and Crow, L. E. Electricity Fundamentals. Indianapolis: Howard W. Sams, 1971.

Gerrish, H. H. Electricity. Chicago: Goodheart-Willcox, 1961.

Herrick, C. N. Electrical Wiring: Principles and Practices. Englewood Cliffs, New Jersey: Prentice Hall, 1975.

Loper, O. E. and Ahr, A. F. Introduction to Electricity and Electronics. Albany, New York: Delmar, 1973.

Middleton, R. G. Practical Electricity. Indianapolis: Howard W. Sams, 1973.

Mix, F. M. House Wiring Simplified. South Holland, Illinois: Goodheart-Willcox, 1973.

Palmquist, R. E. House Wiring. Indianapolis: Howard W. Sams, 1973.

Pipe, Ted. Basic Electricity Training Manual. Indianapolis: Howard W. Sams, 1973.

Rockis, G. Residential Wiring. Chicago: American Technical Society, 1978.

Schick, K. H. Introduction to Electricity. New York: McGraw-Hill, 1975.

RELATED INFORMATION

As with most facets of education, there are information resources available that are well beyond the ability for any individual to digest, let alone completely access. This curriculum package is not intended to spark your interest in curriculum research; it is intended to spark your interest in teaching electricity. Consequently, the additional information useful to this package should be immediately applicable in nature. These are appropriate sources which are listed below.

UTILITY COMPANIES

For example, PEPCO (Potomac Electric Power Company) offers a surprisingly wide range of services including films, publications, demonstrations, visitations, filmstrips, and teaching aids. Other utility companies offer similar services. You should contact your local utility Educational Services Department for information. Contact these people, you will be pleased with the courteous response.

MANUFACTURERS

Look at the electrical equipment around you. Who makes it? Write to the company (your librarian should have access to addresses), tell them what you are doing and ask for anything they can offer.

ASSOCIATIONS

Trade associations and unions will often supply information. Check your local sources first.

RESOURCE GUIDES

There are many sources available through institutions such as Ohio State and Rutgers. The best place to start, however, is by obtaining a copy of the Resource Guide for Performance-Based Electricity/Electronics Instruction available from Western Maryland Vocational Resource Center, P. O. Box 5488, McMullen Highway, Cresaptown, Maryland, 21502, Phone (301) 777-5886. This publication contains a broad range of resources that may prove helpful.